



# Hydrogen Safety

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U.S. Department of Energy



# Hydrogen Fundamentals

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- Energy Content: 60,958 Btu/lb – highest energy content of all fuels on a **weight** basis
  - This is why NASA uses hydrogen – they care a lot more about weight than volume)
  - Energy content is about three times higher than gasoline, natural gas, and propane on a **weight** basis
  - Energy content is only about one third that of natural gas and about an eighth that of propane on a **volume** basis
- Flammability limits (in air): 4.1 v% - 74 v%
- Explosion limits (in air): 18.3 v% - 59 v%

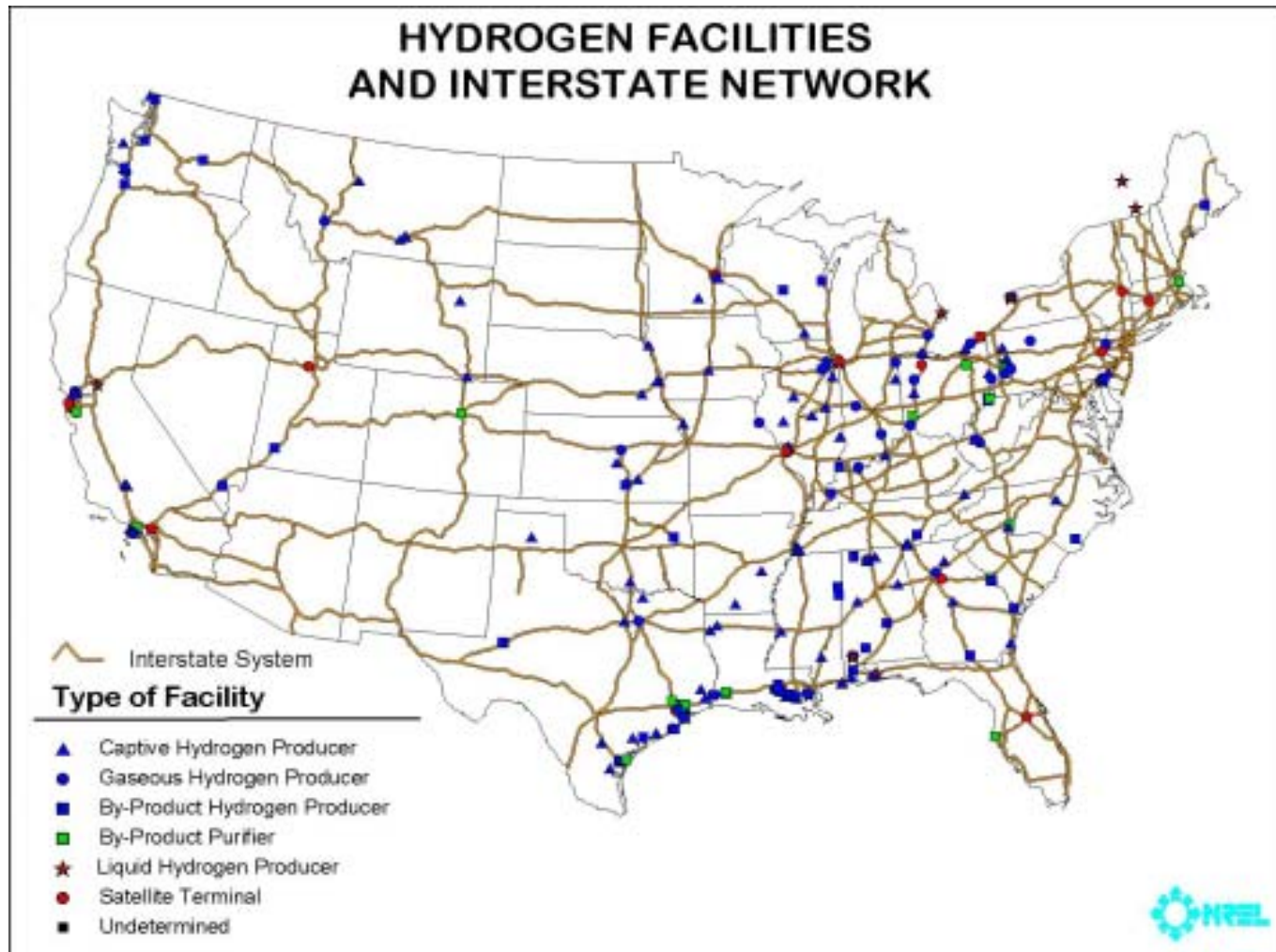


# Hydrogen Today

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- Production (9 million tons per year)
  - Steam methane reforming
  - Electrolysis
  - Byproduct
- Uses – largely in industrial settings
  - Petroleum upgrading
  - Food processing (hydrogenation)
  - Semiconductor processing
  - NASA (only large-scale fuel use)
- Transporting/Delivery
  - Pipeline
  - Liquid tanker
  - Tube trailer (compressed gas)

# Hydrogen Facilities in the US



# NASA's Hydrogen Facilities

Single largest user of  
hydrogen for fuel

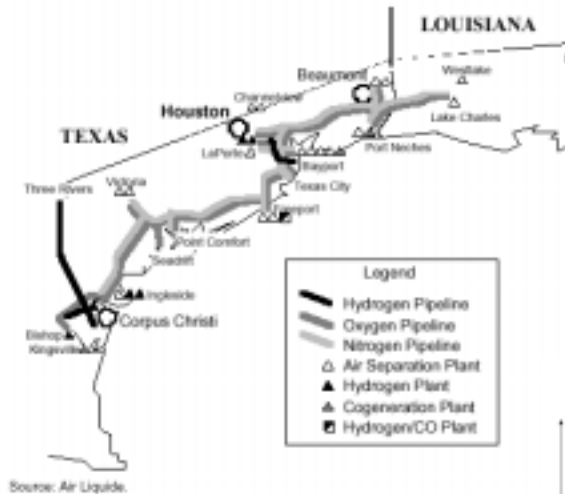
Kennedy Space Center  
850,000 gallon liquid  
storage

Approximately 20 tank trucks  
driven in from Louisiana  
for each shuttle launch

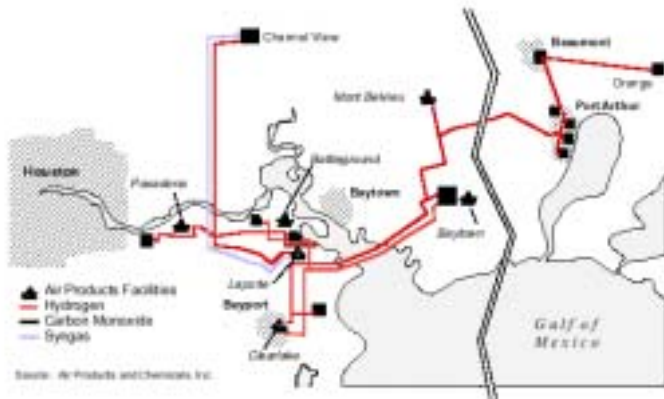


# Hydrogen Pipelines

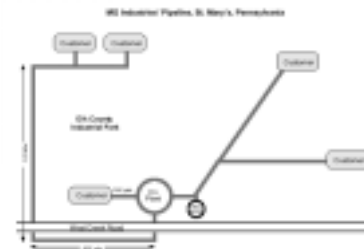
Air Liquide Gulf Coast Pipeline System



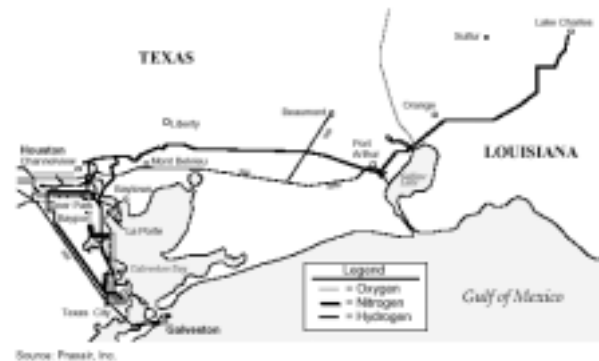
Air Products' U.S. Texas Gulf Coast Hydrogen Pipeline System



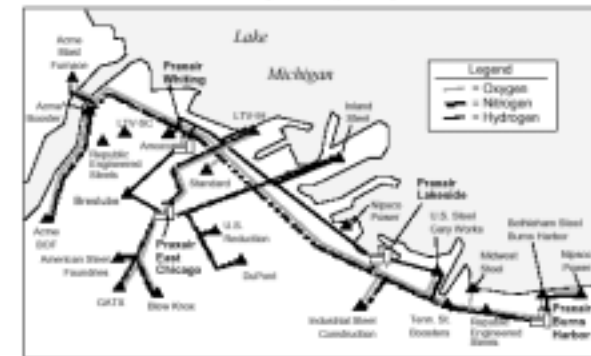
Air Products' Louisiana Hydrogen Pipeline System



Praxair's U.S. Gulf Coast Hydrogen Pipeline System



Praxair's Chicago Area Pipeline System





# Codes and Standards

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- Code-making bodies in the US
  - About 20 major developers (excluding federal agencies such as EPA and DOT)
  - Nearly all is done using a consensus process
- Must be adopted by each jurisdiction to be “legal” and binding
  - Approximately 44,000 jurisdictions in the US
  - Federal, state, county, city or town



# Code Developers

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- International Code Council, Inc. (ICC)
  - Building Officials and Code Administrators International (BOCA)
  - International Conference of Building Officials (ICBO)
  - Southern Building Code Congress International, Inc. (SBCC)
- Underwriters Laboratories (UL)
- National Fire Protection Association (NFPA)
- CSA International
- Society of Automotive Engineers (SAE)
- Institute of Electrical and Electronic Engineers (IEEE)
- American Society of Mechanical Engineers (ASME)
- International Electrotechnical Commission (IEC)
- International Organization for Standards (ISO)
- Compressed Gas Association (CGA)
- Natural Gas Institute (NGI)
- US Department of Transportation
- Occupational Health and Safety Administration (OHSA)





# Issues

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- Codes & standards are being developed in advance of, or in parallel with, hydrogen-fueled systems
  - Codes & standards development must be coordinated with technology development
  - Efforts should be devoted to R&D efforts to validate proposed standards (i.e., need data to support or validate proposed requirements)
- Coordination is vital
  - All applications involve production, transportation, storage, dispensing, and use of hydrogen
  - A large number of organizations are involved in generating codes & standards



# Key Codes

Component Technology	Codes	Status
Production	NFPA 70/ NEC/CEC ASME Boiler-Pressure Vessel Sec. VIII	mature mature
Transportation:	DOT 49 CFR	mature mature
Pipeline	NEC/CEC ANSI/ASME B31.1, B31.8	mature mature
Storage	NFPA 50 A: Gaseous Hydrogen NFPA 50 B: Liquid Hydrogen ASME Boiler-Pressure Vessel Sec. VIII	mature (1994) mature (1994) mature
Vehicle Refueling Stations	HV-3: Hydrogen Vehicle Fuel NFPA 52: CNG Vehicle Fuel HV-1: Hydrogen Vehicle Connector NGV1: NGV connectors	being developed base for HV-3 being developed base for HV-1
Hydrogen Vehicles	HV-3: Hydrogen Vehicle Fuel NFPA 52: CNG Vehicle Fuel HV-2: Gaseous Hydrogen Tanks NGV2: CNG Storage Tanks	being developed base for HV-3 being developed base for HV-2



# ISO-TC197

Identification Number	Title	Working Group	Convener (Country)
DIS 13984	Liquid H <sub>2</sub> - Land Vehicle Fueling System Interface	WG 1	SCC (Canada)
DIS 14687	H <sub>2</sub> Fuel-Product Specification	WG 3	ANSI (USA)
NP 15594	Airport H <sub>2</sub> Fueling Facility	WG 4	DIN (Germany)
NP 15866	Gaseous H <sub>2</sub> and H <sub>2</sub> Blends-- Vehicular Fuel Systems	WG 5	ANSI (USA)
NP 15869	Gaseous H <sub>2</sub> - Vehicle fuel tanks	WG 6	ANSI (USA)
NP 15916	Basic requirements for safety of H <sub>2</sub> systems	WG 7	DIN (Germany)
WD 13985	Liquid H <sub>2</sub> - Land vehicle fuel tank		SCC (Canada)
WD 13986	Tank containers for multimodal transport of liquid H <sub>2</sub>		SCC (Canada)

ANSI/CSA NGV2<sup>1</sup>  
Fuel Containers  
(CNG only)

ASME  
Boiler & Pressure Vessels  
(Published)

SAE J2600  
Fueling Connectors  
(Published)

ICC Family Codes  
Fire, Fuel, Mechanical  
Electrical  
(Approved)

NFPA Codes  
Fuel, Electrical, Storage  
(Under review for H<sub>2</sub>)

ISO TC197 WG5  
H<sub>2</sub> & H<sub>2</sub> Blends  
Refueling  
(Requested)

SAE J2601  
Vehicle Communication  
(In Progress)

UL 2264  
Gaseous H<sub>2</sub> generation  
(To be developed)

ANSI/CSA NGV 4<sup>2</sup>  
Dispensing Systems  
(CNG only)

ISO TC197 WG8  
Water Electrolysis  
(Requested)

SAE J1616  
Recommended Practice  
(CNG only)



CGA G-5.3 Hydrogen  
Commercial Specification  
(Published)

CGA P-6 Hydrogen  
Standard Density Data  
(Published)

CGA G-5 Hydrogen  
Commercial H<sub>2</sub>  
(Published)

CGA G-5.4 Hydrogen  
Piping Systems  
(Published)

ISO TC-197 WG2  
Tank Containers  
(Requested)

CSA FC-4  
Fuel Cell Modules  
(Proposed)

ANSI Z21.83/CSA FC-1  
Fuel Cell Powerplants  
(Under revision)

IEC TC 105 WG5  
FC Installation  
(Initiated)

IEC TC105 WG1  
Terminology  
(Under review)

ICC Family Codes  
Fire, Fuel, Mechanical  
Electrical  
(Approved)

NFPA Codes  
Fuel, Electrical, Storage  
(Under review for H2)

ISO TC 197 WG2  
Containers & Hydrides  
(In Progress)

CSA CAS No. 33  
Component Acceptance  
Service  
(Published)

ASME PTC 50  
Performance Test  
(Approved)

UL 2265  
Replacement FC units  
(Under development)

ISO TC 58  
Tanks & Embrittlement  
(Requested)



IEC TC105 WG2  
FC Modules  
(Under review)

IEC TC 105 WG3  
FC Safety  
(Draft in progress)

CSA US Requirements 1.01  
FC supplemental  
(Published)

UL 1741  
Inverters & Converters  
(Under draft)

CGA G-5.4  
H2 Piping at Consumers  
(Published)

NFPA 853  
FC Installation  
(Under revision)

IEEE P1547  
Interconnect Standard  
(Approved)

ASME B31.4  
Pipeline Transportation  
(Published)

NFPA 58  
Transport of LPG  
(Published)

DOT 49 CFR  
Transportation of  
Hazardous Materials

ASME B31.8  
Gas Transmission &  
Distribution  
(Published)

ISO TC 197 WG2  
Containers & Hydrides  
(In Progress)

CSA CAS No. 33  
Component Acceptance  
Service  
(Published)

NFPA 55  
Combined 50 A&B  
(In progress)

Part 1910 29 CFR  
OSH Standards  
(Published)

ISO TC 58  
Tanks & Embrittlement  
(Requested)

DOT Guide  
First Responders on  
Emergencies  
(Published)



ASME  
Boiler & Pressure Code  
(Published)

NFPA 50B  
Liquid H2 Systems  
(Published)

CGA G-5.4  
H2 Piping at Consumers  
(Published)

NFPA 50A  
Gaseous H2 Systems  
(Published)

CSA/NGV2  
Fuel Tanks for Hydrogen  
(Requested)

SAE J2600  
Compressed Hydrogen  
Fueling Connectors  
(In Progress)

SAE J2574  
Fuel Cell Vehicle  
Terminology  
(Published)

SAE J2594  
Fuel Cell Recyclability  
Guidelines  
(In progress)

SAE J2572  
Recommended Practice  
Exhaust Emissions  
(In Progress)

SAE J2615  
Performance Test Procedures  
For Fuel Cell Systems  
(In progress)

SAE J2601  
Compressed Hydrogen  
Fueling Communication  
(In progress)

SAE J2616  
Performance Test Procedures  
For Fuel Processor Subsystem  
(In progress)

SAE J2578  
Recommended Practices  
For Vehicle Safety  
(Published)



DOT/NHTSA  
Vehicle  
Regulations

SAE J2617  
Performance Test Procedures  
Of PEM FC Stack Subsystem  
(In progress)

SAE J2579  
Recommended Practices  
For Hazardous Fluid Systems  
(Published)

ISO TC 197  
Compressed Hydrogen  
Fueling Connectors  
(Requested)



# Hydrogen Uses - Tomorrow

- Mobile Applications

- Fuel cell vehicles (buses, trucks, passenger)
- Modified ICEs



- Stationary Applications

- Uninterruptible power supplies
- Backup/premium power
- CHP



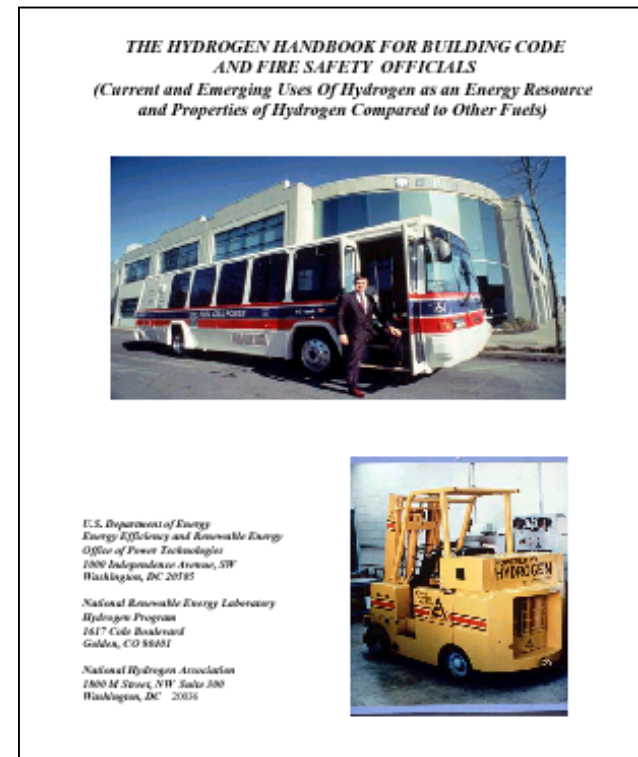
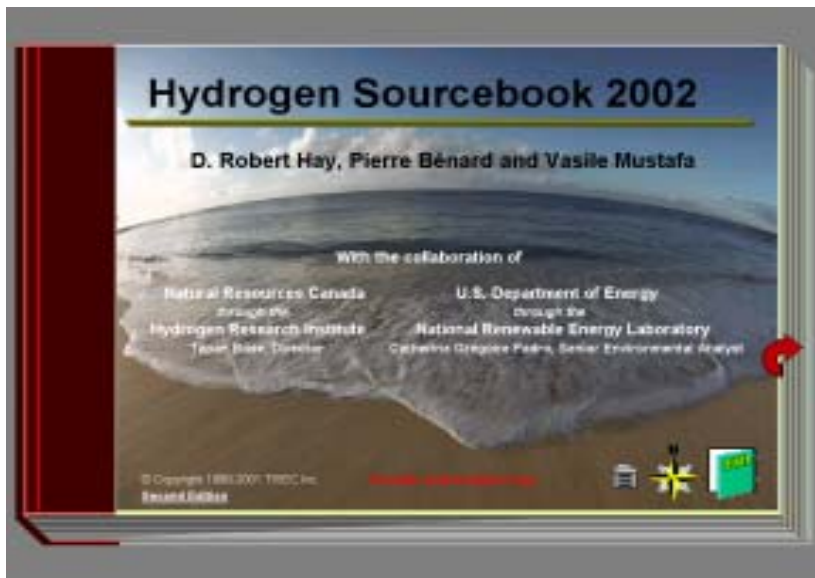
- Portable Applications





# Guidelines for Hydrogen Systems

- The Hydrogen Handbook for Building Code and Fire Safety Officials
- The Hydrogen Sourcebook





# Typical Hydrogen Site Plan Review

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- Confinement
- Review Potential for Ignition
- Minimizing Consequences
- Review the Need for Detectors
- Safety Analysis
- Review Site-Specific Factors
- Personal Investigation

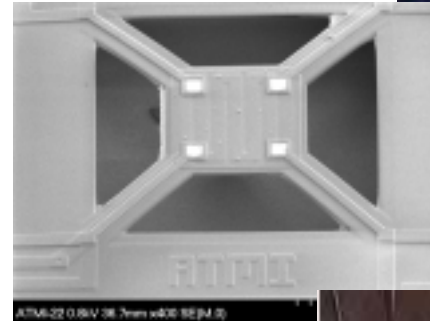
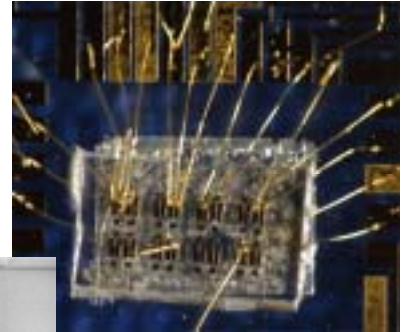
# Detection

- Sensors

- Safe, reliable, cheap sensors being developed
- Placement is important

- Odorants

- Diffusion/dispersion matching is difficult
- Poison to fuel cell?





# Safe Hydrogen Systems

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- Safety issues can be handled through testing, certification, and codes & standards, just like with any other fuel
- Sustained, collaborative government-industry RD&D needed
  - Fuel cell and vehicle systems development are critical
  - Infrastructure and codes & standards development require significant government participation (on all levels)
  - Coordination is key



**For more information:**

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